Device SEE Susceptibility Update: 1996-1998

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Abstract

This eighth Compendium continues the previous work of Nichols, et al, on single event effects (SEE) first published in 1985. Because the Compendium has grown so voluminous, this update only presents data not published in previous compendia.

I. Introduction

SEE test programs have continued for several years at the Jet Propulsion Laboratory (JPL), Aerospace Corporation, (ARSP) Goddard Space Flight Center (GSFC), and the European and French Space Agencies (ESA and CNES) to assess device susceptibility to heavy ion and/or proton environments. More recently, organizations such as Space Electronics, Inc (SEI), Matra-Marconi Space (MMS) and Saab have been making significant contributions in this research area. Seven compendia have been published by JPL since 1985 in the IEEE Transactions on Nuclear Science [1, 2, 3, 4] and the Radiation Effects Data Workshop Records [5, 6, 7].

Other testing compendia have been presented by other experimenters [e.g. 8, 9, 10]. However, these compendia have usually contained only that data produced by the test organization.

II. Testing Approaches

The testing approaches used by all these organizations, while similar, are not identical. Additionally, all these techniques are constantly evolving and moving more and more to computer-control. In general, the testing procedures follow those outlined in the ASTM F1.11 or JEDEC 13.4 documents [11, 12] on single event testing.

III. Data Organization and Scope

This paper summarizes single event upset (SEU) and latchup (SEL) data from 1996 to 1998 from numerous sources. Some additional data from earlier years has come to light and is included, as well as a limited data set on proton displacement damage. Single event gate rupture (SEGR) or burnout (SEB) of power transistors is not included, but has previously been presented in the Radiation Effects Data Workshop Records [13, 14, 15]. There is also a limited set of published SEE data using neutrons [8, 16], that is also presented.

The data reported in the tables is substantially abbreviated, generally including only thresholds and saturation cross sections, and ignores any statistical features. The data has been excerpted directly from the referenced reports, but in some cases data is not shown because only reduced data was shown in the reference. In these instances, the reference is for completeness only, and the reader should contact the original author(s) for clarification. Because of different definitions of what constitutes threshold (no upsets, cross section at 10% of saturation, etc.), the user would be advised to review the original reference for the author's definition of "threshold". Although we have endeavored to provide the user with data source references, because of processing changes it is always advisable to consider a test on the actual flight lot, particularly if the Compendium shows that a device may be marginal for a given mission.

Previous Compendia versions presented predominantly heavy ion data, with a few entries on proton testing. Because of the significant amount of work performed in the past few years with proton accelerators, this

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data has been separated out into separate tables. Table 1 shows data from heavy ion testing while Tables 2 and 3 show proton data. Table 4 presents the small amount of available neutron-induced SEE data. The Compendium layout from previous years has also been somewhat modified to make it easier to use.

In addition to dividing heavy ion and proton data into separate tables, other significant changes were removal of latchup information from the remarks and placing it into separate columns, thus providing more comprehensive data sets. These changes allow the user to quickly scan a row and, where it exists, get both upset and latchup phenomena data.

IV. Heavy Ions

Because of the interest in using commercial-off-the-shelf (COTS) devices in space, the bulk of the work in recent years has concentrated on this class of parts. Designers are particularly interested in these devices because of their capabilities and speed, which are typically superior to most "rad-hard" devices. Foremost in most modern-day designs is the desire for massive amounts of data collection. To this end, much of the more recent testing has concentrated on high-density memories, FPGAs and 32-bit microprocessors.

The desire for reliability has also fostered a higher interest in SEL rather than SEU. Upsets can usually be ameliorated with proper software or hardware design [17], but a SEL failure can result in loss of an entire mission. It is recognized that SEL susceptibility may have a strong temperature dependence [18], but temperature data is often not presented in the original reference. Whenever temperature information is noted in the reference, this data is shown in the remarks column. Unless an elevated temperature is noted, the data is assumed to be taken at device ambient operating temperature, which may, or may not be, the same as room temperature.

V. Protons

As COTS devices get smaller and require less charge to initiate an upset, they are trending toward an increased sensitivity to protons that can be in the form of SEU, SEL, single event transients (SET) or displacement damage. Similarly, to testing done with heavy ions, much of the proton testing has been done with an eye toward handling massive amounts of data on the spacecraft.

Recent data has also shown that optical devices, such as some optocouplers and/or infrared LEDs, may be quite vulnerable to proton-induced upset, latchup or degradation. This is evidenced by the amount of optocoupler data in Table 2, as well as on-orbit SET data from the Hubble Space Telescope [19].

Other recent data has also shown that many optoelectronic and bipolar linear circuits may also be vulnerable to proton-induced displacement damage (Table 3). The vulnerability of optocouplers to degradation has been predicted and documented on the TOPEX-Poseidon spacecraft [20]. While not technically a SEE, this data has been included here for completeness.

VI. Conclusions

The latest available heavy ion and proton-induced SEE data on microcircuits has been gathered from multiple test laboratories and placed into general device categories. Data on proton displacement damage in selected device types is also presented. The data presented here, along with all previous data, can be found on JPL's World Wide Web site at *radnet.jpl.nasa.gov*.

VII. References

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